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EXPLORATORY FACTOR ANALYSIS & ASSESSMENT OF ENERGY POTENTIAL OF GENERATED SOLID WASTE IN NIGERIA

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ABSTRACT

Exploratory Factor Analysis (EFA) is a complex and multivariate statistical method usually employed in psychology, health related professions and more recently in information system was adopted in this study. It makes use of correlation matrix to determine the relationship between variables. Data used for this study involves both primary and secondary. The collected data were mainly on the physical component of the generated solid waste from six (6) geopolitical zones within Nigeria (the study area). Also, proximate and ultimate analyses were used to obtain the energy potential of generated solid waste from the six (6) zones. The results from the analyses using EFA and Proximate & Ultimate Analyses for energy potential proved that one could make energy potential projections using data from about four geopolitical zones (North-Central, South-Southern, South-Western and South-Eastern) or three geopolitical zones (South-Southern, South-Western and South-Eastern) and achieve about 98% high decision precision without losing much of the relevant details.

Key words: Exploratory Factor Analysis (EFA), Multivariate, Energy Potential and Geopolitical Zones, Nigeria

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1. INTRODUCTION

Generated solid waste varies from country to country. The difference in composition of solid wastes generated from both developed and developing countries is likely to vary widely. The solid waste from a developing country is characterised majorly by organic content when compared with the one generated from developed nations [1]. The rate of solid waste generation by a country or region is usually a function of the economic activities within that nation [2] and as such developed countries tend to generate more waste than developing countries [3]. Based on accessibility of economic resources and the extent of mechanisation and availability of technological resource, Nigeria as a nation can be regarded as a developing nation [4].

Research conducted [5] has it that when organic materials degrade biologically they yield energy in form which can be utilized effectively in the right conditions. Also, components of solid waste streams have an inherent energy value or potential that can be tapped through various technological processes as alternative source of energy. The energy content of solid waste is the heat of combustion (higher or lower heat of combustion) released when waste is burnt [6]. The Lower heat of combustion usually excludes the heat of vaporization of water unlike the higher heat of combustion. The composition of a waste stream is an important feature required in determining the choice of waste-to-energy process that is technically and economically achievable for the given waste stream.

The energy potential of the organic components of solid waste can be harnessed basically through two methods: (i) Thermo-chemical conversion; and (ii) Bio-chemical conversion (see Table 1). Waste-to-Energy conversion processes usually yield by-products such as oil, steam, gas, and heat. The components usually employed in recovering useful energy from the generated by-product of the conversion process typically include electric generators, steam and gas turbines, and boilers. Other promising waste-to-energy conversion procedure includes Slurry Carb Process and Plasma Pyrolysis Vitrification (PPV).

Table 1 Waste-to-Energy Conversion methods and Conversion Processes

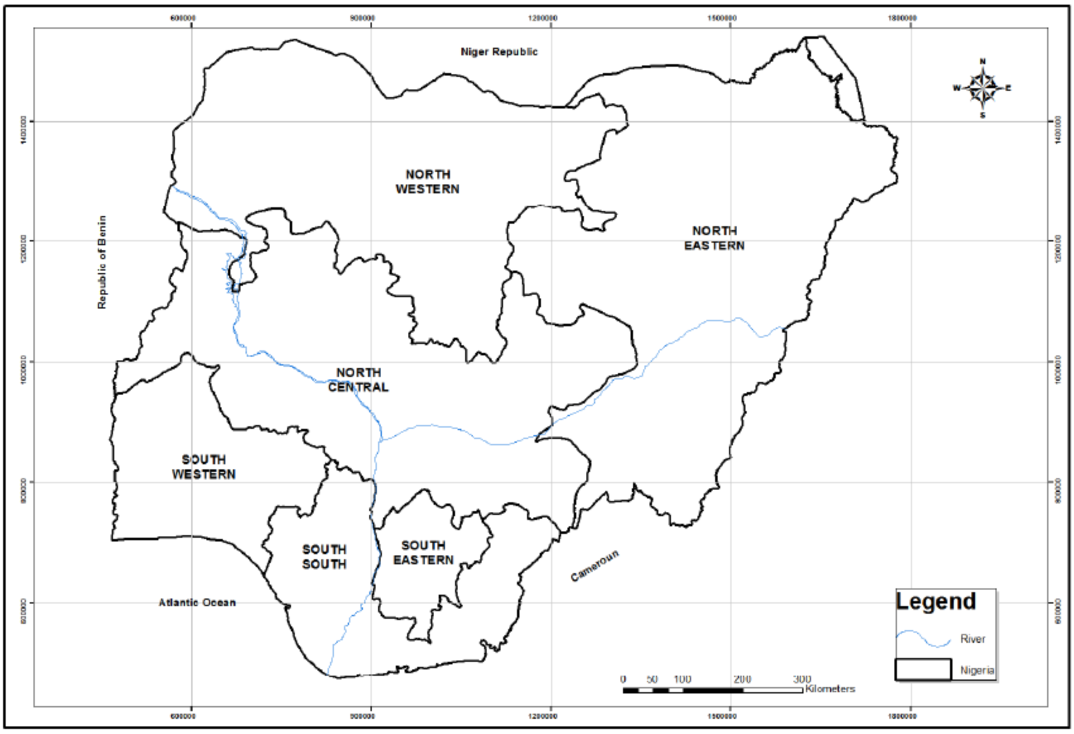
Waste-to-Energy Conversion Method	Waste-to-Energy Conversion Process	Decomposition Factor
Thermo-chemical Conversion	Incineration	Decomposition of organic matter by heat
	Gasification/ Pyrolysis	
Bio-chemical Conversion	Anaerobic Digestion/Bio-methanation	Decomposition of organic matter by microbial action
	Sanitary Landfill/Bio-reactor	

Exploratory factor analysis (EFA), which is commonly employed in information system [7] is a complex and multivariate statistical method that allows for the creation of a theory or model drawn from the exploration of the main variables of a data set. Ming-Yang Wu and Kuo [8] applied factor analysis in monitoring the air pollution status of central Taiwan, classifying the air quality status and identifying the dominant pollutant in the district. Also, Gashasbi and Others [9] applied factor analysis to assess the use of information technology amongst experts and top management in the department of education and also to pinpoint the difficulties working against the progress of information technology application in the educational sector of Khuzestan province in South-Western Iran.

2. MATERIALS AND METHODS

2.1. Study Area

Nigeria, as our study area lies between longitude 3°E and 15°E and latitude 4°N and 14°N with six geopolitical zones: North-East, North-Central, North-West, South-East, South-South and South-West (see Figure 1). It is located on the Gulf of Guinea in West Africa. It has a land area of 923768sq.km and borders with Chad and Cameroon in the East, the Republic of Benin in the West, Niger in the North and the Atlantic Ocean in the South. Its coastline is at least 853km long. Nigeria has two (2) main rivers (Niger and Benue) that forms a confluence and empties into the Atlantic Ocean *via* the Niger Delta, the World's largest river delta [10]. In Nigeria there are thirty-six (36) States, one (1) Federal Capital Territory, and seven hundred and seventy-four (774) Local Government Areas with population growth rate that ranges between 2.38 and 3.0 [10, 11]. The average population of Nigeria was about 170 million people at 2012 with a projected population number of about 184,869806 people in 2015[12].



(**Source:** Awopetu el ta[13])

Figure 1 Map of Nigeria with the six (6) administrative geopolitical zones

2.2. Data Collection

Data was collected from both primary and secondary sources. In order to ensure a detailed representation of solid waste management in Nigeria, data on solid waste management were collected from at least a major city within the six (6) geopolitical zones of the nation from literature and field survey. Also employed in data collection were focused group discussions involving professional environmentalists and solid waste managers. Table 2 presents the States within the six (6) geopolitical zones in Nigeria while the solid waste composition of State(s) from the six(6) geopolitical zones in Nigeria are as per Table 3.

Table 2 States within the six (6) geopolitical zones in Nigeria

North-East (NE)	North-Central (NC)	North-West (NW)	South-West (SW)	South-South (SS)	South-East (SE)
Adamawa State	Benue State	Jigawa State	Lagos State	Edo State	Abia State
Bauchi State	Kogi State	Kaduna State	Osun State	Delta State	Anambra State
Borno State	Kwara State	Kano State	Oyo State	Rivers State	Imo State
Gombe State	Nasarawa State	Katsina State	Ogun State	Cross-River State	Enugu State
Taraba State	Niger State	Kebbi State	Ekiti State	Akwa-Ibom State	Ebonyi State
Yobe State	Plateau State	Sokoto State	Ondo State	Bayelsa State	
		Zamfara State			

Table 3 Solid waste physical composition from the six(6) geopolitical zones

Zone	Components / States	Organics	Plastics	Paper	Glass	Metal	Textile/ leather	Unclassified Debris
NE	*Borno (Maiduguri)* [a]	25.8	18.1	7.5	4.3	9.1	3.9	31.3
NC	*Niger* [b]	31	16	13	9	11	6	14
	Nasarawa [c]	31.5	7.25	3.5	18	6.5	1.5	31.75
	Abuja [d]	43.57	20.97	23.11	3.23	3.79	2.77	2.56
NW	*Kano (Sabon-gari)* [e]	57.5	17.5	6.7	5.7	3.9	4.5	4.2
SW	*Oyo (Ibadan)* [f]	47	12.6	21.9	0.9	6	8.8	2.8
	Lagos [g]	53	15	10	5	5	4	8
	Ogun (Ota) [h]	42.07	21.01	8.29	9.59	1.06	7.44	10.54
SS	*Rivers (Port Harcourt)* [i]	63	3.5	9.9	1.9	3.4	14	4.3
	Delta [j]	37	21	18	6	10	5	3
	Cross-River (Calabar) [k]	23.33	14.67	16	12	15.33	0	18.67
SE	*Enugu (Onisha(2006))* [l]	30.7	9.2	23.1	9.2	6.2	6.2	15.4
	Enugu (Onisha(2010)) [m]	47	17.9	8.1	4.5	8.7	10.1	3.7

Sources: Dauda and Osita [14][a];Ejaro and Jiya [15][b];Anyanwu and Adefila [16][c];Adati and Others [17][d];Bichi and Amatobi [18][e];Kayode and Omole [19][f];Yetunde [20][g];Olukanni and Mnenga [21][h]; Babatunde and Others[22][i];Egun [23][j]; Afangideh and Others [24][k]; Ogwueleka [25][l];Nwachukwu [26][m].

2.3. Data Analysis

Exploratory factor analysis was employed in analysing the collected data inorder to obtain the corralations betweeen variables of the generated waste. These analyses includes test of hypothesis, Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, Bartlett's test of sphericity and Principal Component Analysis (PCA) (using XLSTAT). Also, based on *as discarded basis*, Proximate and Ultimate analyses were applied into analyzing the collected data inorder to obtain the energy potential of the generated solid waste from the six(6) geopolitical zones in Nigeria.

2.3.1. Exploratory Factor Analysis

The approach usually taken in Exploratory Factor Analysis, EFA is usually sequential and linear involving many options [27, 28]. It employs correlation matrix to determine the relationship between variables. According to Harman [29] and Coughlin [30], Equation (1) presents the '*classical'* factor analysis model. The coefficients for the common factors also known as 'factor *loading*' is represented by '*a*' in Equation (1).

$$Z_J = a_{j1}F_1 + a_{j2}F_2 + a_{j3}F_3 + \ldots + a_{jm}F_m + u_jY_j \quad (j = 1,\ 2, 3, \ldots, n) \tag{1}$$

where Z_j is an observed variable being described by the linear combination of common factors (F_1, F_2, F_3,…,F_m) and u_jY_j represents a unique factor.

The factor model in Equation (1) can be rewritten as presented in Equation (2) when considering the value of a specific variable '*j*' for a given individual observation '*i*'.

$$Z_{ji} = \sum_{p=1}^{m} a_{jp} f_{jp} + u_j Y_{ji} \tag{2}$$

With respect to this study, the six (6) geopolitical zones are the variables being studied while the observations are the physical components of the generated solid waste from these zones. These physical components includes the organic, plastic, paper, glass, metal, textile/leather and unidentified contents of the generated solid waste.

In EFA, five (5) steps are usually involved. This includes the determination of: i) data suitability; ii) method for factor extraction; iii) criteria for factor extraction; iv) rotational method for factor loading; and v) variable attributes to factors (i.e. result interpretation). Figure 2 presents a flow chart of the general steps involved in conducting an exploratory factor analysis.

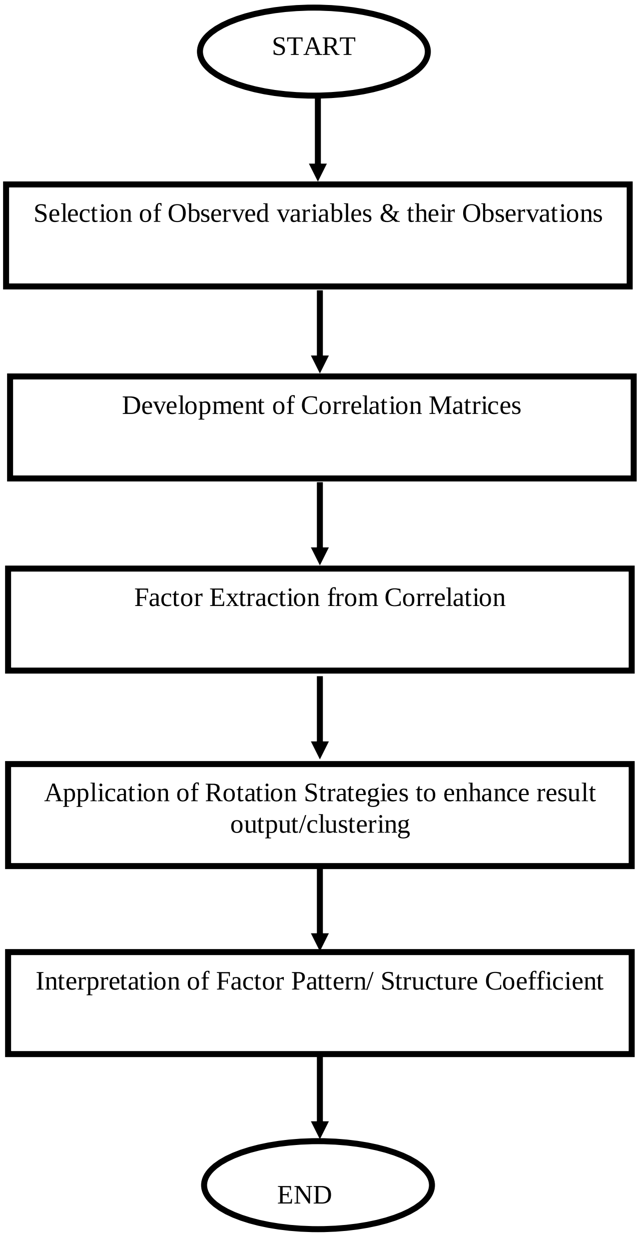


Figure 2 Flow chart of general steps involved in exploratory factor analysis

2.3.2. Kaiser-Meyer-Olkin (KMO) Measure of Sample Adequacy/Bartlett's Test of Sphericity

This measures how strong the partial correlations amongst variables/items (whether they are small or large) checking their adequacy with respect to the analysis. According to Netemeyer [31], *KMO* must have a correlation above 0.6-0.7 for the sample data to be considered adequate. Also, a chi-square output is provided by the Bartlett's test of Sphericity indicating the suitability/significance ($p<0.05$) of the data for factor analysis [32]. Equation (3) presents the *KMO* measure of sample adequacy:

$$KMO = \frac{(\Sigma\Sigma r_{ij}^2)}{((\Sigma\Sigma r_{ij}^2)+(\Sigma\Sigma a_{ij}^2))} \quad (3)$$

Where: a_{ij}^2= partial correlation between variable *i* and *j*;

r_{ij}^2 = variance between variable *i* and *j*.

2.3.3. Principal Component Analysis (PCA)

With respect to this study, Principal Component Analysis was used on a matrix of Pearson correlation coefficients to extract maximum variance from the data set. It is a technique that uses sophisticated underlying mathematical principles to transform a number of possible correlated variables into a smaller number of artificial variable (called principal component) thereby extracting factors of communality and identifying patterns in data sets. This is one of the major advantages of using PCA in factor extraction from data sets without lossing much of the information.

2.3.4. Scree Test for Factor Extraction

Factor extration criteria was determined using the scree test. This invloves the visual exploration of a graphical presentation of the eigenvalues for breaks or discontinuities between the components with relatively large eigenvalues and those with small eigenvalues is looked out for. The components that appear before the break are presumed to be meaningful and are retained for rotation while those appearing after the break are assumed to be unimportant and not retained.

2.3.5. Rotational method for factor loading

This is a technique that tends to minimize low item/factor loading and maximizes high item/factor loading producing a more interpretable and simplified solution. The Orthogonal Varimax rotational technique which is mostly used in factor analysis was applied for this analysis due to its ability to produce factor structures that are uncorrelated.

2.4. Proximate and Ultimate Analyses

Proximate analysis is a chemical classification that determines the amount of some proxy or stand-in parameters in place of the true chemical content [6]. The ultimate analysis of solid waste components helps in defining the right mix of waste material to obtain a suitable carbon to nitrogen ratio (C/N) for biological conversion processes [33]. It involves the determination of the percentage of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulfur (S) and ash.

3. RESULTS AND DISCUSSION

3.1. Results

A graphical presentation of collected data on the physical composition of the generated solid waste from the six geopolitical zones is presented in Figure 3, while Figure 4 present the average composition of the generated solid waste from Nigeria as a nation. On applying Exploratory Factor Analysis on the collected data from the State(s) within the six (6) geopolitical zones in Nigeria, Tables (4-7) present the various results obtained from the analysis. These include results on: Pearson n-1 variable correlation matrix, Kaiser-Meyer-Olkin (KMO) measure of sample

adequacy/Bartlett's Test of Sphericity, the test of hypothesis, and Principal Component Analysis for factor extraction on communality of the data set from the study area.

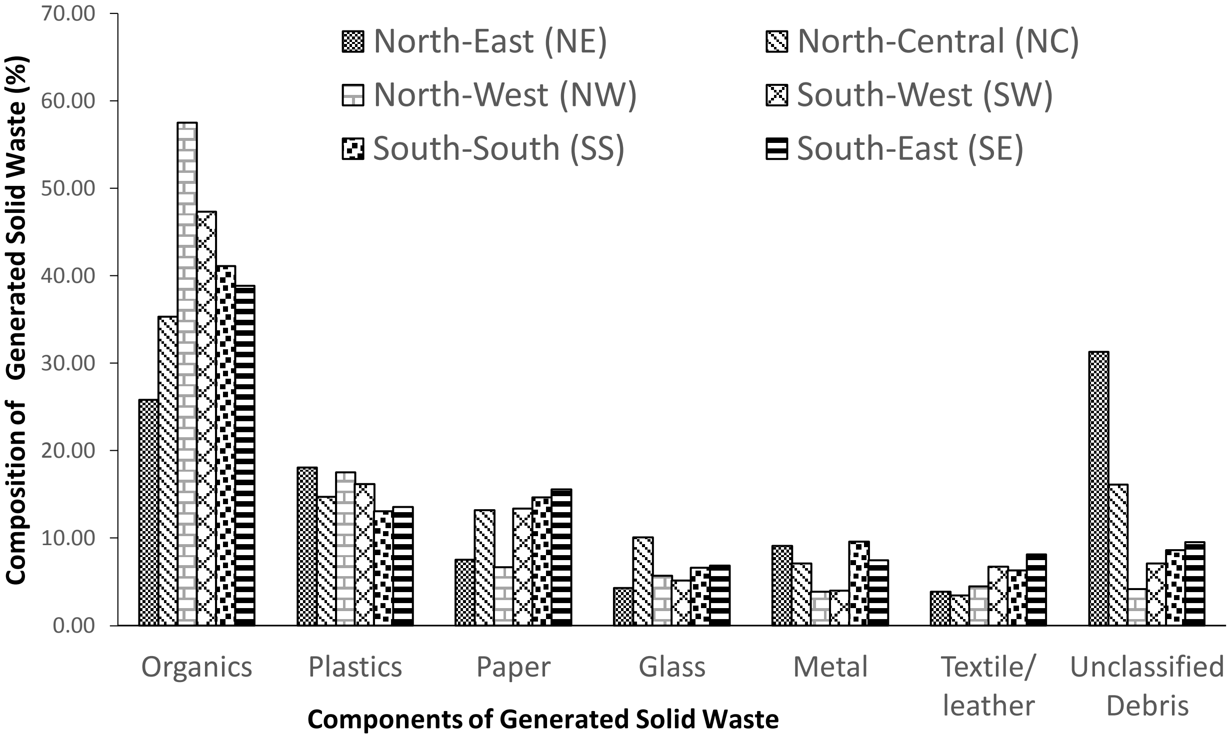


Figure 3 Physical Components of Generated Solid Waste from Nigeria Six (6) Political zones

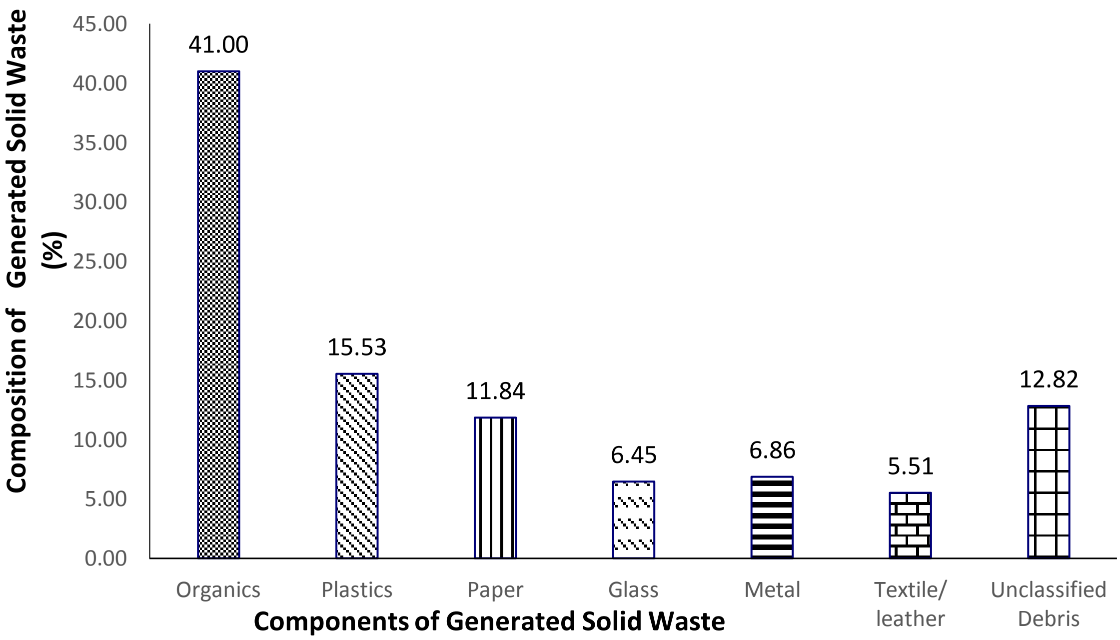


Figure 4 Average physical components of generated solid waste in Nigeria

Table 4 Correlation± matrix (Pearson (n-1))

Variables	**North-East (NE)**	**North-Central (NC)**	**North-West (NW)**	**South-West (SW)**	**South-South (SS)**	**South-East (SE)**
North-East (NE)	**1**	0.7029	0.4897	0.4946	0.4856	0.4905
North-Central (NC)	0.7029	**1**	**0.9223**	**0.9339**	**0.9354**	**0.9363**
North-West (NW)	0.4897	**0.9223**	**1**	**0.9868**	**0.9730**	**0.9691**
South-West (SW)	0.4946	**0.9339**	**0.9868**	**1**	**0.9860**	**0.9933**
South-South (SS)	0.4856	**0.9354**	**0.9730**	**0.9860**	**1**	**0.9940**
South-East (SE)	0.4905	**0.9363**	**0.9691**	**0.9933**	**0.9940**	**1**

±***Note:*** *Values in bold are different from 0 with a significant level (alpha) = 0.05*

Table 5: Bartlett's sphericity test

Chi-square (Observed value)	55.7519
Chi-square (Critical value)	24.9958
DF	15
p-value	< 0.0001
Alpha	0.05

Table 6 Kaiser-Meyer-Olkin measure of sampling adequacy

North-East (NE)	0.6828
North-Central (NC)	0.8489
North-West (NW)	0.6136
South-West (SW)	0.6152
South-South (SS)	0.6397
South-East (SE)	0.6040
KMO	0.6550

Principal Component Analysis (PCA)

The resultant eigenvalues and percentage variability from the data analysis (Principal Component Analysis) used for factor extraction on applying exploratory factor analysis technique is presented in Table 7.

Table 7 Resultant Eigen values from PCA

	F1	F2	F3	F4	F5	F6±
Eigenvalue	5.1907	0.7254	0.0429	0.0294	0.0111	0.0004
Variability (%)	86.5117	12.0896	0.7158	0.4905	0.1853	0.0071
Cumulative %	86.5117	98.6013	99.3171	99.8076	99.9929	100.0000

± FI to F6 are **e**xtracted factors from the principal component analysis

Figures 5-7 present plots used for factor extraction of the principal component analysis of the collected data set.

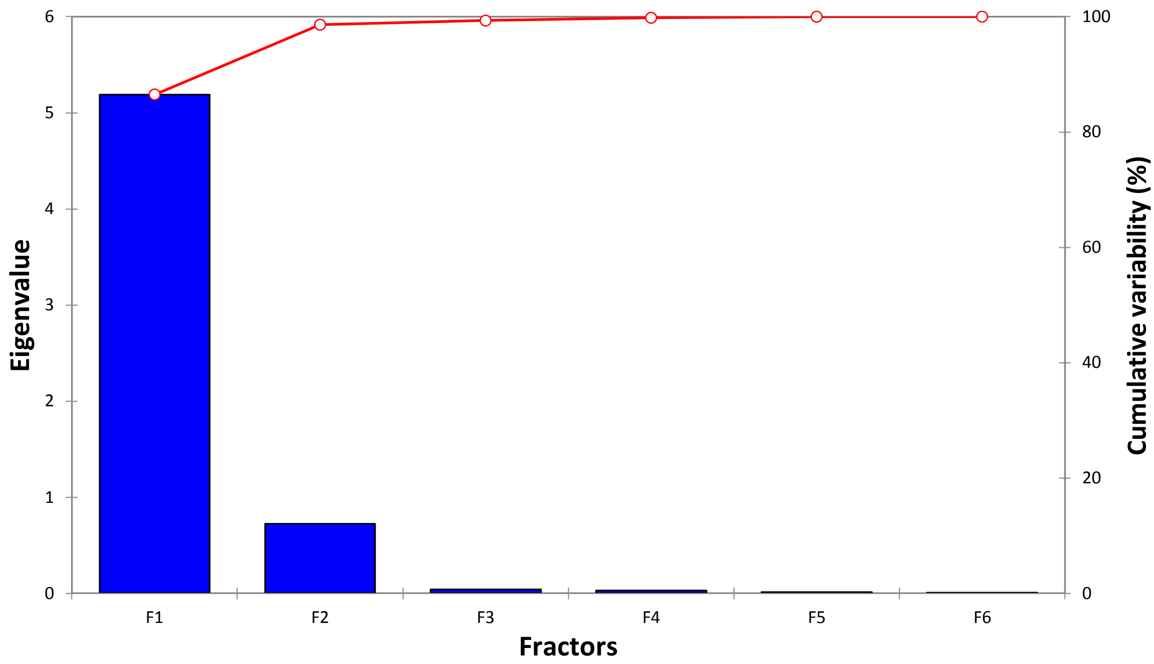


Figure 5 Scree plot for factor extraction among Nigeria 6 Geopolitical zones

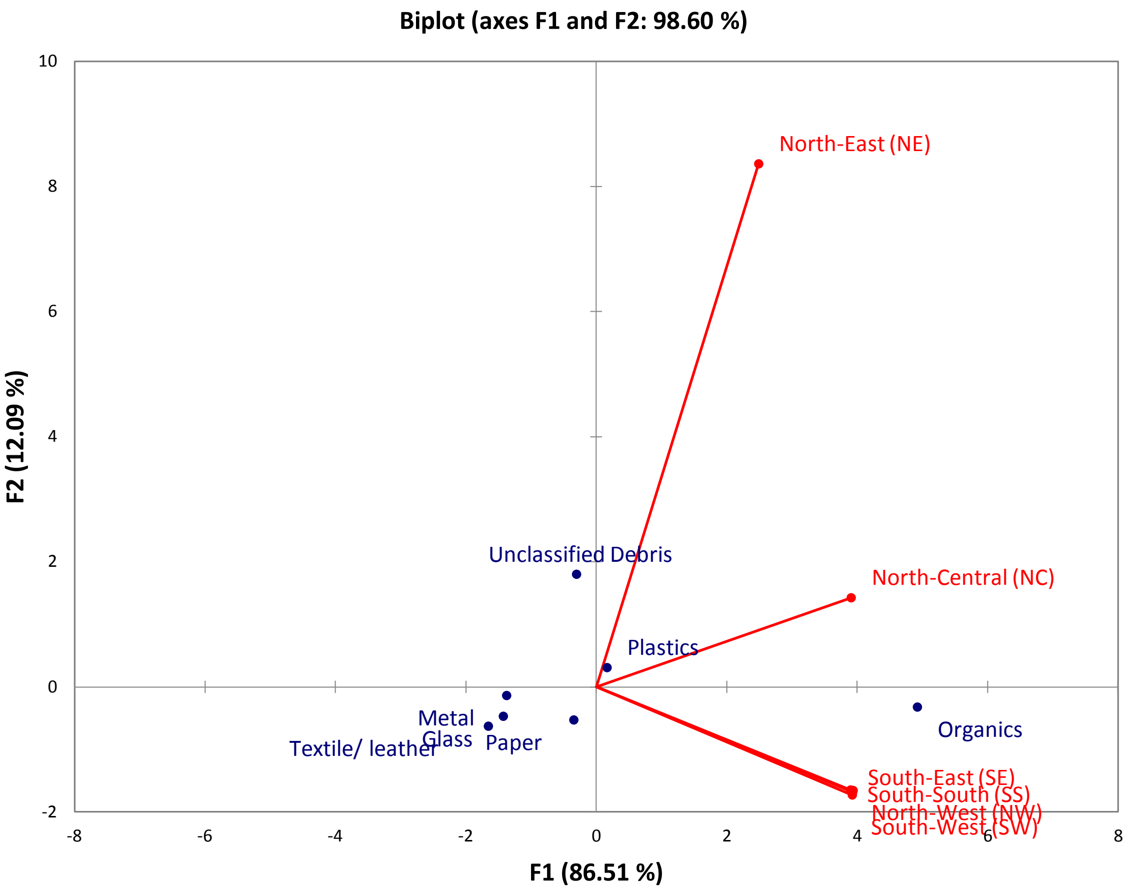


Figure 6 Biplot of correlation between observations *(Physical components of generated solid waste)* and factors on correlation between variables *(Nigeria 6 geopolitical zones)* and factors

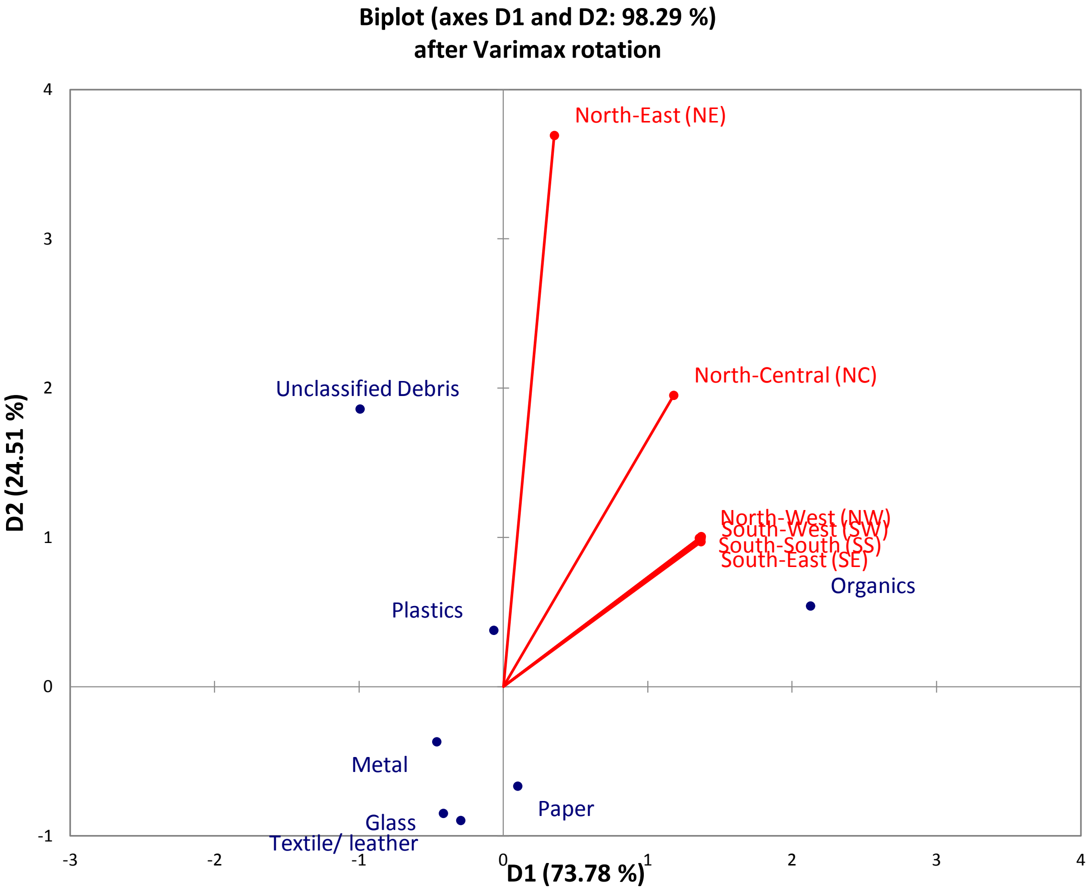


Figure 7 Biplot of correlation between observations and factors on correlation between variables and factors after Varimax Rotation for factor loading

The results on the energy potential from the generated solid waste within the study area on application of proximate and ultimate analysis are presented in Table 8.

Table 8 Energy Potential of Generated Solid waste from 6 Geopolitical Zones

NGPZ[¥]	As discarded Basis		Dry Basis		Dulong's Formula (KJ/Kg)	Empirical Formula
	H.Heating Value (KJ/Kg)	L.Heating Value (KJ/Kg)	H.Heating Value (KJ/Kg)	L.Heating Value (KJ/Kg)		
NE	10624.711	10285.788	13648.500	13061.716	26775.694	$C_{607}H_{880}O_{196}N_{14}S$
NC	11419.712	10982.830	16060.032	15559.141	23488.476	$C_{591}H_{868}O_{249}N_{15}S$
NW	11674.779	11237.231	19414.297	18898.666	22656.835	$C_{597}H_{865}O_{263}N_{19}S$
SW	12265.700	11793.197	18555.892	18049.649	22560.388	$C_{598}H_{883}O_{268}N_{19}S$
SS	11849.306	11372.160	17523.312	17035.053	22401.081	$C_{575}H_{854}O_{262}N_{18}S$
SE	12195.449	11714.280	17534.897	17027.491	22674.319	$C_{582}H_{869}O_{260}N_{19}S$
[±]PCA	11996.730	11530.011	18240.723	17736.384	22574.213	$C_{588}H_{868}O_{263}N_{19}S$

[±]PCA = Principal Component Analysis of 6 Geopolitical Zones with relatively equal properties
[¥] NGPZ = Nigerian Geopolitical Zones

4.2. DISCUSSION

The physical composition of solid waste from the North Eastern zone shows relatively low correlation when compared with the other zones (see Table 4). While the North Central, North Western, South Southern, South Western and South Eastern zones show relatively high correlation amongst the generated solid waste data from these zones.The results from the Bartlett's shpericity test and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is presented in Tables 5 & 6, respectively. The chi-squared output provided by the Barlett's sphericity test involves a null hypothesis *(H_0)* and an alternative hypothesis *(H_a)* being:

H_0: There is no correlation significantly different from zero (0) between the generated solid waste composition from the geopolitical zones; and

H_a: At least one of the correlations between the generated solid waste composition from the geopolitical zones is significantly different from 0.

As the computed p-value *(<0.0001)* is lower than the significance level, alpha = *0.05*, one should reject the null hypothesis H_0, and accept the alternative hypothesis H_a. The risk to reject the null hypothesis H_0 while it is true is lower than *0.01%*. The KMO measure of sampling adequacy resulted in a value equal to *0.6550* which is above *0.6* indicating that the sample adequacy for this analysis is acceptable and as such a Principal Component Analysis (PCA) on the data set would provide an adequate factor analysis.

As presented in Table 7 Principal Component Analysis (PCA) generate factors which are linear combination of the initial variables (geopolitical zones) using the Pearson correlation matrix (see Table 4). The resultant eigenvalues corresponding to the generated factors show the variability of each factor to the initial data set. As seen in Table 7, factor 1 (F1) alone contributes *86.5%* of the initial variability of the data, thus a projection made using factor 1 (F1) as a criteria will have a good quality of *86.5%* of the initial data set (various components of the generated solid waste from Nigeria). Also, a projection made using the factors 1 & 2 (F1 & F2) will give a better quality of *98.6%* of the initial data set. The Scree plot (see Figure 5) is a plot of the Eigenvalue against percentage cumulative variability for factor extraction. It shows a deviation/break after factor 2, this implies that factors 1 & 2 can be extracted to make projections with little or no deviation from the entire data set.

The biplots (see Figures 6 & 7) present a two dimensional plot of factor loading/scores (*see Appendixes A1 & A2*) of the physical components of generated solid waste from the geopolitical zones and the square cosine of the variables (geopolitical zones) with respect to factors 1 & 2 (Principal Component Factor).Also, from the biplots the identity of the principal factors extracted is identified with Factor 1 representing the organic component of the generated solid waste and factor 2 representing the *unclassified debris* components of the generated solid waste (*see also Appendixes A3 & A4*). Meanwhile, North Eastern & North Central zones are unique in terms of their organic and *unclassified debris* solid waste components when compared with the other zones whose organic and *unclassified debris* contents of the solid waste are closely correlated (see Figures 6 & 7).

Applying Proximate and Ultimate Analyses on the collected data,yields the results presented in Table 8 for the energy potential of the generated solid waste from the various zones. The results of the computed energy potential from the zones with respect to the analysis using the pricipal components gave approximately equal and

high correlation value(*see Appendix A5)* with the energy potentials from the geopolitical zones within the study area.

5. CONCLUSION

Nigeria as a nation is made up of six geopolitical zones, these zones comprise various States with different ethnic and cultural practices, population size, and socioeconomic level. These factors amongst other tend to influence the physical composition of the solid waste generated from each zone. The result obtained from the application of Exploratory Factor Analysis on the generated solid waste from these Zones proved that despite the various differences in level of development, socioeconomic level, and cultural practices there is really no significant difference in the composition of the physical components of the generated solid waste from these zones. Also, the study reveals that one could use the solid waste data obtained from South Western, South Southern, South Eastern, and North Western zones to make reasonable predictions / analyses of the potential energy content of the generated solid waste without losing much of the information when compared with the solid waste data obtained from Nigeria as a nation. Thus, enforcing the claim that Exploratory factor analysis could be used to simplify or reduce a data set without lossing significant details of the initial data set and yet achieve an acceptable result [34, 35].

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APPENDICES

A1: Factor scores:

Observation	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**
Organics	4.9259	-0.3254	0.0300	0.0081	0.0317	0.0094
Plastics	0.1673	0.3052	0.2162	0.0666	-0.0835	-0.0366
Paper	-0.3428	-0.5315	-0.3678	-0.1481	-0.0762	-0.0116
Glass	-1.4237	-0.4728	-0.0831	0.3417	-0.0035	0.0116
Metal	-1.3728	-0.1408	0.0286	-0.0786	0.2176	-0.0107
Textile/ leather	-1.6531	-0.6314	0.2486	-0.1626	-0.0737	0.0230
Unclassified debris	-0.3008	1.7968	-0.0724	-0.0271	-0.0124	0.0148

A2: Squared cosines of the variables: ±

Variables	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**
North-East (NE)	0.3878	0.6092	0.0015	0.0014	0.0000	0.0000
North-Central (NC)	0.9546	0.0176	0.0148	0.0129	0.0001	0.0000
North-West (NW)	0.9501	0.0238	0.0205	0.0050	0.0006	0.0000
South-West (SW)	0.9694	0.0240	0.0020	0.0005	0.0039	0.0002
South-South (SS)	0.9630	0.0261	0.0019	0.0032	0.0057	0.0000
South-East (SE)	0.9658	0.0246	0.0022	0.0063	0.0009	0.0002

±*Values in bold correspond for each variable to the factor for which the squared cosine is the largest*

A3: Contribution of the observations (%):

	F1	F2	F3	F4	F5	F6
Organics	77.9089	2.4335	0.3493	0.0368	1.5042	3.4816
Plastics	0.0899	2.1399	18.1340	2.5123	10.4595	52.3787
Paper	0.3774	6.4905	52.5092	12.4235	8.6949	5.2187
Glass	6.5080	5.1369	2.6812	66.1344	0.0183	5.2356
Metal	6.0514	0.4557	0.3174	3.4977	70.9542	4.4380
Textile/ leather	8.7740	9.1608	23.9764	14.9808	8.1397	20.6825
Unclassified debris	0.2905	74.1828	2.0325	0.4144	0.2292	8.5649

A4: Squared cosines of the observations for the 6 Geopolitical Zones ± :

	F1	F2	F3	F4	F5	F6
Organics	0.9956	0.0043	0.0000	0.0000	0.0000	0.0000
Plastics	0.1550	0.5157	0.2587	0.0246	0.0386	0.0074
Paper	0.2087	0.5016	0.2403	0.0390	0.0103	0.0002
Glass	0.8537	0.0942	0.0029	0.0492	0.0000	0.0001
Metal	0.9621	0.0101	0.0004	0.0032	0.0242	0.0001
Textile/ leather	0.8472	0.1236	0.0192	0.0082	0.0017	0.0002
Unclassified debris	0.0272	0.9709	0.0016	0.0002	0.0000	0.0001

±Values in bold correspond for each observation to the factor for which the squared cosine is the largest

A5: Correlation of Resultant Energy Potential Values Between the 6 Geopolitical Zones

	NE	NC	NW	SW	SS	SE	PCA
NE	1						
NC	0.965892	1					
NW	0.796675	0.925958	1				
SW	0.855552	0.960422	0.994471	1			
SS	0.896942	0.98084	0.981749	0.996283	1		
SE	0.912259	0.987208	0.97425	0.992532	0.999348	1	
±PCA	0.867687	0.966807	0.991692	0.999714	0.998056	0.995159	1

±PCA = Geopolitical Zones with relatively equal properties from Principal Component Analysis